It will be noticed that the 6-year, 3-year, and 9-year series accord perfectly in indicating a progressive change in the ratio due to variation in ground-water flow from month to month, and that the multiplication of data has the usual effect of smoothing irregularities in the curve. All three agree in showing the high annual ratio of 65 per cent. It need hardly be stated that the values are found not by averaging the ratios but by computation from the means of the sums of the quantities involved (rainfall and outflow), due weight being given to the number of days per month. Additional interest is given by the fact that the region is densely forested, and thus in a natural condition.

TABLE 1.—*Rainfall and outflow in the Valley of the Chagres above Bohio, 700 square miles.*

Months.	Mean depth of rainfall in millimeters.			Mean outflow in cubic meters per second.			Ratio.*		
	6 years.	3 years.	9 years.	6 years.	3 years.	9 years.	6 years.	3 years.	9 years.
January	147	106	133	122.5	76.8	100.6	1.18	1.07	1.12
February	27	20	25	40.5	39.6	40.2	2.00	2.64	2.15
March	34	27	32	25.7	26.4	25.9	1.11	1.44	1.20
April	75	155	103	33.5	49.7	38.9	0.64	0.46	0.54
May	266	319	284	57.6	73.6	62.9	0.32	0.34	0.33
June	270	286	275	84.3	90.9	86.5	0.44	0.45	0.45
July	394	319	369	124.5	113.6	120.9	0.46	0.53	0.48
August	361	341	354	139.0	120.1	132.7	0.58	0.52	0.55
September	291	285	289	130.3	142.4	134.3	0.65	0.71	0.66
October	361	277	333	164.3	145.6	158.1	0.68	0.78	0.70
November	432	412	425	226.5	193.5	215.5	0.75	0.67	0.72
December	176	220	191	133.5	182.0	149.7	1.14	1.22	1.16
Year	2834	2767	2812	106.8	104.5	106.0	0.65	0.65	0.65
3 dry months	136	202	158	33.2	38.6	35.0	1.05	0.82	0.95
9 rainy mos	2698	2565	2654	131.4	126.5	129.8	0.63	0.63	0.63

*See Monthly Weather Review, February, 1904, Vol. XXXII, pp. 60–63.

TABLE 2.—*Disposition of rainfall above Bohio (based on records for nine years, 1898–1906).*

Months.	Mean rainfall in inches.	Mean outflow in feet-seconds.			Mean outflow in inch-miles.			Evaporation in inch-miles.
		Total.	Direct flow.	Ground water.	Total.	Direct flow.	Ground water.	
January	5.24	3552	951	2603	5.86	1.57	4.29	Negative.
February	0.99	1420	20	1400	2.11	0.03	2.08	Negative.
March	1.26	915	23	892	1.51	0.03	1.48	Negative.
April	4.06	1374	763	611	2.19	1.22	0.97	1.87
May	11.19	2222	2020	202	3.65	3.32	0.33	7.54
June	10.84	3055	2037	1018	4.87	3.25	1.62	5.97
July	14.54	4269	2668	1601	7.03	4.39	2.64	7.51
August	13.95	4687	2556	2131	7.73	4.21	3.52	6.22
September	11.39	4743	2157	2586	7.57	3.44	4.13	3.82
October	13.12	5585	2393	3192	9.20	3.94	5.26	3.92
November	16.74	7613	3172	4441	12.13	5.05	7.08	4.61
December	7.52	5288	1368	3920	8.70	2.25	6.45	Negative.
Year	110.84	3727	1677	2050	72.55	32.70	39.85	38.29
3 dry mos	6.31	1236	269	967	5.81	1.28	4.53	0.50
9 rainy mos	104.53	4557	2147	2410	66.74	31.42	35.32	37.79

These statistics throw an interesting light upon the ultimate disposal of rainfall in this basin. It was shown in the former paper, based on six years' records, that the ratio in five subdivisions for the minimum month, that of May, was 0.30 ± 0.03. This figure is confirmed by the three additional years now available, for which it was 0.34. Since May is at the end of the long, dry season, it is fair to assume that in it the flow of ground water has practically ceased. If so, the ground flow during each month of the year may be computed from the above data, since it is equal to the measured monthly flow less the product of this quantity by the quotient of 0.30 divided by the observed monthly value of the ratio. The accompanying Table 2 exhibits the result of such a computation in the seventh and eighth columns. The figures are given in English units, and in a form directly comparable with the rainfall. This comparison between direct and ground-water flow will be found interesting; the latter curve passes thru a minimum in May and a maximum in November, and its progressive character conforms to what might be expected from gradual seepage thru the earth under the rainfall conditions; the curve of direct flow has also a natural form, and indicates that without the ground flow the river would run nearly or quite dry in February and March, as do now most of its smaller tributaries.

Classing as evaporation the difference between rainfall and total river flow, the values may be expected to vary considerably from month to month; but the mean for the year, representing a complete cycle, should show a value approximately correct. This value is shown to be 38.29 inches, or about one-tenth of an inch per twenty-four hours. Direct measurements by the pan method have very recently been inaugurated on the Isthmus. They show for December, 1906, 0.135 inch per twenty-four hours; for January, 1907, 0.167 inch, and for February, 0.181 inch.

PANAMA RAINFALL.

By E. B. GARRIOTT, Professor of Meteorology.

Like other tropical regions that are swept by winds from the ocean, the Panama Canal Zone, in latitude about 9° north, has fairly well-defined wet and dry seasons. The wet season extends from April or May to November or December, and is called the *invierno;* the dry season extends from December to April, and is called the *verano*. In August there is in Central America an interval of comparatively dry weather that is called the *veranillo*, or *little verano*, or the *verano de Augusto*.

The rains of the wet season come in the form of local thunderstorms that are often torrential in character. In April and May they are usually confined to the late hours of the afternoon; they increase in duration and intensity until in June they often continue during the afternoon and night; they then decrease until August, after which they increase until the approach of the second maximum period of October or November, and then decrease until December.

The immediate cause of the rains of the wet season is found in the shifting of the equatorial rain belt that attends the sun in its annual march north of the equator, and the periods of maximum rainfall occur about the time the sun is in the zenith of Panama, the spring maximum attending the northward movement of the rain belt, and the autumn maximum its return southward movement. During the August interval of comparatively settled weather, which is more marked on the coast than in the interior, the equatorial rain belt is north of Panama.

The annual rainfall is much heavier on the Atlantic than on the Pacific side of the Canal Zone, the amount being about 157 inches at Colon (Aspinwall), and about 67 inches at Panama. At Gamboa, on the watershed at an elevation of about 102 feet, the annual rainfall is a little less than 100 inches. Rains that occur during the dry season are infrequent and comparatively light, and are produced by what are termed "northers" that in the winter months are sometimes felt as far south as Panama, and are also due to the trade winds that at times strike the Isthmus after crossing the warm Caribbean Sea.

On the Caribbean side of the Isthmus the dry season is confined practically to the months of January, February, and March, and the heaviest rains of the year are likely to occur in April. On the watershed of the Canal Zone the first four months of the year are usually dry, the spring maximum occurs in May, and the rainfall of the August *veranillo* is frequently heavy. The August interval of dry weather of the Central American countries as a whole is in fact inconspicuous along the Canal Zone. On the Pacific side of the Isthmus the wet season extends from May to November, inclusive, with periods of maximum rainfall in June and November, and the dry season of December to April, inclusive, is better defined than on the watershed and on the Atlantic side.

The mornings of the wet season are, as a rule, cool and fresh. Preceding and during the afternoon and night rains, however, the atmosphere is sultry and oppressive, and in the low-lying Atlantic end of the Canal Zone the heat is particularly trying. In the dry season of the winter and early spring months temperatures are usually pleasant, except during the prevalence of "northers" when the weather is sometimes disagreeably cool.

At no point in the Canal route does the elevation above sea level exceed 300 feet. The entire strip may, therefore, be placed in the "hot zone", a term that is applied to portions of the Central American coast districts that are less than 300 or 400 feet above the level of the sea. The Atlantic, or Caribbean Sea, side of the Isthmus is, however, lower, hotter, more humid, and more malarial than the Pacific side. At Colon the April rainfall averages about 36.5 inches, which equals the annual rainfall in the Middle Atlantic States of the United States. The November rainfall at Colon is nearly 23 inches, and the so-called August dry interval yields about 15 inches. On the watershed the monthly rainfall amounts to about 13 inches in May, September, October, and November, with a maximum of 14 inches in August. At Panama the maximum, about 12 inches, occurs in November, and 7 to 9 inches falls monthly from May to October, the least amount during this period being about 7 inches, in August. Daily rainfalls of 5 to 7 inches and hourly amounts of 1 to 2 inches are not uncommon in the Canal Zone during the wet season.

In plans for the construction and operation of the Canal the importance of the study of the vicissitudes of Panama rainfall can not be overestimated. The rainfall element does not enter so largely into the problem of a sea-level canal; in a lock canal, however, whose feeders are subject to sudden and violent floods, a due consideration of the variability, intensity, and duration of rainfalls, and of possible periodicities in years of excessive rains, is of the utmost importance. Periodicities in maximum and minimum rainfall periods are most likely to be defined in the equatorial rain belt, for in this region the association with terrestrial and solar causes of meteorological effects is undoubtedly the most apparent, and it is here that variations in primary causes can be the more readily detected by means of observed facts. In an adjustment of available Central American rainfall observations made in 1895, Professor Harrington[1] noted a succession of maxima and minima of annual rainfalls, with intervals of recurring years of unusually heavy rains that ranged from five to eight years, and an average interval between the maxima of six years.

Aside from the value that may be attached by meteorologists to investigations of the periods of excess and deficiency in Panama rainfall, the results of investigations of this kind are calculated to be of practical value to engineers and of interest to the American public. In short, the construction of a lock canal in a part of the equatorial rain belt that is visited by seasonal downpours, which at intervals of several years are likely for periods of days and perhaps months to be abnormally heavy, presents a new and most important problem in canal construction.

[1] Phil. Soc. of Wash., Bul., Vol. XIII, pp. 1–30.

OBSERVATION OF CLOUD ALTITUDES AT NIGHTTIME.

In 1872 the Editor had occasion to make a report to the Chief Signal Officer on the importance of observing clouds, their altitudes, motions, and phenomena in greater detail than was common at that time. Among many methods recommended he enumerated the use of small balloons, filled with hydrogen gas, each carrying a long thread, by means of which its initial vertical velocity and its subsequent altitude could be determined at any time, whenever it entered or emerged from a cloud. The necessary balloons and instructions for using this method were furnished for the use of the arctic expedition of the schooner *Florence* in 1877.

Among other methods for permanent use at a fixt station, and as almost the only method appropriate for work at nighttime, he urged that within a few miles of an observer, a searchlight should be stationed, pointing vertically upward, and thus illuminating a circular patch of cloud or haze at the zenith.

The above methods are also described on pages 311 and 323 of the editor's "Meteorological apparatus and methods". He has often urged that this latter method of observation at nighttime is one of great value, likely to give us many new ideas as to the growth and structure of clouds. It is, therefore, with peculiar pleasure that we learn from the Geographical Journal, February, 1907, that Dr. J. Reden, assistant at the astronomical observatory at Vienna, has independently hit upon the same method, making use of the electric reflectors of the Leuchtbrunnen, or luminous fountain, erected at a point on the Ringstrasse, about a mile from the observatory. The observer has merely to measure the apparent angular altitude of the center of the luminous spot in the sky. The tangent of this angle, multiplied by the distance of the vertical beam of light, gives the linear height of the cloud. The first measurements were made June 14–24, 1906, and elevations between 5100 and 33,000 feet were soon measured. When the lower layer of clouds is thin it has become possible to detect three successive layers. The writer adds:

> The new method surpasses in exactitude the most trustworthy of the methods hitherto applied, viz, the photogrammetric, determining as it does the altitude in question with positive accuracy. It is hoped to start a systematic course of such observations in other parts of the earth as well. There is no doubt that not only for science, but also for practical weather forecasts, such observations will prove highly serviceable.

FOG ON THE NEWFOUNDLAND BANKS.[1]

By C. T. BRODRICK. Dated Harvard University, Cambridge, Mass., March 22, 1907.

During the greater part of the year the route for high-powered steamers between Nantucket Lightship and Fastnet or the Scilly Islands crosses the forty-seventh meridian to the south of latitude 43° north, making a considerably greater distance to be traversed by thus avoiding the Grand Banks. This circuitous route is taken because of the fog and the ice found in this district during the spring and summer months. Numerous collisions with other vessels and with icebergs occur every year, and some accidents in the past have been accompanied by large loss of life.

The occurrence of fog about the coasts of Newfoundland and farther north was noted by some of the earliest explorers of the regions—Cook, Ross, Parry, and others.[2] They remarked on its density, that it did not extend to any great height above the water, and that it was most prevalent with southerly winds. Some interesting speculations on the causes of these fogs are set forth at considerable length in Henry Ellis's "Voyage to Hudson's Bay," (1748).[3] His fantastic theories are in strange contrast with our present ideas, even with his own considerable accuracy of observation.

In 1822 Scoresby[4] published some data which he had accumulated during the previous summer. His general conclusions were that fogs are more prevalent during the summer months, that they have an average thickness of from 150 to 250 feet, and that they are accompanied by inversions of temperature.

[1] This article was prepared as a part of my college work in an advanced course in meteorology and climatology, under Prof. R. DeC. Ward. My original intention was to add some charts embodying the information kindly sent me by Mr. James Page, of the U. S. Weather Bureau, but the present work is principally bibliographic and historical. The article by Mr. Proctor, in the January, 1907, Review, was not available for me until after I had finished this work.

[2] Cf. Bibliography under Muncke.

[3] Cf. Bibliography: Ellis.

[4] Cf. Bibliography: Scoresby.